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(9) MPL TECHNICAL MEMORANDUM 217

(6) A DESCRIPTIVE SUMMARY OF THE
RUM- ORB SEA FLOOR WORK SYSTEM.

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(11) 17 Aug 1970

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(15) Sponsored by
Office of Naval Research
Contract N00014-69-A-0200/6002
NR 260 103

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A Descriptive Summary of the
RUM - ORB Sea Floor Work System

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I. SYSTEM

A. Operational Data:

> RUM is an unmanned track laying, bottom crawling sea floor work vehicle. It is connected to the surface support ship by a single coaxial cable, through which all vehicle power, control and instrumentation telemetry and television video is transmitted. The cable also serves as the strain member for lowering RUM to the sea floor. RUM is mobile yet firmly coupled to the bottom for stability in the performance of work tasks. ←

B. Operations Crew:

RUM is operated by a three man crew, a driver, a navigator and an operations director. Two to three additional people are used to perform maintenance tasks and as divers for disconnect and hook-up of snubbing cables during launch and retrieval.

ORB (oceanographic research buoy), the surface support vessel, carries a crew of four, thus nine to ten people are employed in a RUM operation. With twelve people on board it is possible to conduct continuous around the clock 24-hour a day operations.

C. and D. Typical Operations and Operational History:

Actual at-sea operation of RUM began in January 1970, with the emphasis on system test, debugging, evaluation and operator training. Operations have been conducted off the Coronado Strand in 125-ft depths, the San Diego Trough at 3300 feet and in the La Jolla Canyon at 1200 to 1350 feet. Over 100 hours of time on the bottom have been logged with a total distance of over 6 miles driven. Navigation and manipulation exercises have been conducted. The most encouraging operation was just completed on August 6, in which 28 continuous hours of operation on the floor of the La Jolla Canyon were logged with all systems functioning well. In excess of 2000 feet of traverse over the soft sediments was made at depths ranging from 1200 to 1350 feet. An acoustic navigation transponder, placed on the canyon floor near the north wall at 1330 feet in April of this year, was located and recovered by RUM on August 6.

E. Major Components of System:

Major components of the work system are the RUM vehicle and ORB (the surface support vessel).

II. VEHICLE

A. Size	Length	OAL	15'0"
	Width	OAL	8'7"
	Height	OAL	10'9"

B. Weight in air 23,250 lbs; in water 12,750 lbs. Area of track contact with sea floor 4000 sq. in. Tread pressure 0.2 to 3 psi depending on cable tension. Draw bar pull 1,000 to 5,000 lbs. depending on bottom and cable tension.

C. Operating depth to 6,000 feet. Can be extended to 10,000 feet.

D. Payload 2,000 lbs. 20 cubic feet.

E. Speed over the bottom 0 to 100 feet/minute.

F. Endurance. Indefinite, depending only on reliability and on the availability of operators.

G. Power requirements. 25 KVA 240 volt 60 Hz 1 phase; 2 KVA 120 volt 60 Hz 1 phase (vehicle and control console); 30 KVA 240 volt 60 Hz 3 phase (handling winch); transmission line voltage is 2400 volts rms 60 Hz.

H. Vehicle Subsystems and Equipment**1. Propulsion**

Two 7-1/2 hp 850 RPM series wound DC motors (General Electric modified for increased brush pressure, i.e., 15 to 20 psi). Motor driven variac into silicon rectifiers for speed control. Solenoid actuated brakes.

2. Search and Navigation

- a. Scanning sonar (MPL design and fabrication) 125 kHz,
360° scan

PPI display, 75-ft range.

Bearing resolution $\approx 3^\circ$.

Range resolution ≈ 1 ft.

Display in relative bearing with magnetic north pulse on perimeter of display.

- b. Magnetic compass. Vehicle heading with calibrated corrections for deviation applied $\pm 4^\circ$.
MPL fabrication.

- c. Depth sounder.
39 kHz 4 digit readout.
Maximum range 6,000 feet.

- d. Track turns counts for distance traveled over the bottom.
- e. Acoustic transponder system.
 - Interrogate on 8.5 kHz.
 - Three transponders answer on 7.75, 9.25 and 10 kHz.
 - Range 20 to 5,000 feet.
 - MPL design and fabricate.
- f. Three TV cameras.
 - MPL design and fabricate.

3. Manipulator

"General Mills" model 500 hot lab manipulator with modified seals and oil-filled with pressure compensation for salt water immersion (all dc electric motor driven).

Manipulator is mounted on a boom for elevation and rotation around a king post at the rear of the vehicle. Maximum lift on boom \approx 500 lbs. Maximum force exerted by manipulator in any direction at arms length \approx 50 lbs. Maximum grip opening-7". Maximum height of reach - 8 feet. Boom rotate speed - 45°/minute. Boom raise lower speed - 5 feet/minute. Shoulder rotate speed - 3°/second. Arm raise lower - 2°/second. Elbow raise lower - 2°/second. Wrist rotate speed - 1.5 RPM. Grip open, close - 0.25 inches/second.

4. Structural

With the exception of the TV cameras containing vidicons which must be protected from the ambient pressure all components are immersed in oil and pressure equalized for full exposure to ambient pressure. Compartment walls are part of the chassis structure. Covers are flacid diaphragms for pressure equalization.

The strain members of the support cable are terminated by epoxy encapsulation cast into the termination block. This is attached to an asymmetrical tripod lift structure which allows the manipulator to be stowed compactly. The tripod lift structure has one leg in extreme tension, one in compression and the third stabilizing leg has nearly neutral stress.

5. Cables and Penetrators

With the exception of a half-dozen cable glands used to seal inter-compartment cables and the main high voltage umbilical coaxial cable where it enters the vehicle, all cable connections are made using a variety of "Vector Marsh & Marine" connectors molded onto cable ends.

III. CABLE ASSEMBLY

Length: 10,000 feet
Diameter: 0.842 inches
Weight: \approx 8,000 lbs
"U.S. Steel Tiger brand special amergraph cable armored type"
Surge impedance: 52 ohms
DC resistance: shield braid 15 ohms; center conductor 18 ohms.

This cable has a coaxial core with essentially the characteristics of an RG 8A/U except that the voids surrounding the center conductor and shield braid strands are filled with a special semi-conducting compound to reduce noise and raise the corona starting level. Corona starting level is rated 7 kV. Rated breaking strain is 60,000 lbs. The epoxy cast strain member termination has been tested for yield above 40,000 lbs.

IV. CONTROL, INSTRUMENTATION AND POWER CONVERSION EQUIPMENT

A. Instrumentation

Outputs from a variety of sensors on the vehicle are telemetered to the readouts on the control console via 64 channels of time multiplex telemetry and 8 amplitude modulated carriers. Clock waveform and data frame synchronization pulse for the time MPX are transmitted down cable on a 1 MHz AM carrier while data up cable is on a 250 kHz AM carrier. The other 8 AM carrier telemetry channels are distributed through the frequency band 1930 kHz to 2440 kHz.

Telemetry channel function assignments are all listed in reference 1.

B. Control Console

The operator or driver control console measures approximately 5 feet high by 4 feet wide by 3-1/2 feet deep and contains all controls for driving, manipulation, positioning TV cameras, adjusting sub-system operating parameters, etc. In addition, readout of depth, vehicle attitude, control positions, operating conditions, sonar, compass, TV, etc. are displayed.

Three TV cameras on the vehicle may be viewed one at a time at the console or two on a time-share basis with reduced picture resolution. The TV video is transmitted up the cable as the lower sideband on a 9 MHz AM carrier. TV band is 5 to 9 MHz.

Control functions are transmitted down to the vehicle via 64 channels of time MPX telemetry on a 833-1/3 kHz AM carrier and 4 other AM carrier telemetry channels. Channel function assignments are listed in the "RUM vehicle system description."

C. Vehicle Tracking

Bottom mounted acoustic transponders are used for tracking the vehicle. The transponders and interrogate system are of MPL design and fabrication. Position relative to ORB is indicated by the wire angle of the taut cable.

D. Power Conversion

Primary power to the vehicle is 240 V AC 60 Hz 1 phase. This is transformed to 2400 V AC and coupled to the coaxial cable for transmission to the vehicle through a cross-over filter network which isolates power source from signal circuits. Another identical cross-over filter network in the vehicle separates signal and power frequencies. The power is transformed back to 3-wire 120-240 V single phase for propulsion and other motor driven systems on the vehicle. A "Georator" motor generator is used to generate 2 KVA of 120 volts 3 phase 400 cycle power 2% regulation for line voltage variations of 100 to 280 V, for electronics power supplies. Silicon rectifiers are used where dc power is required as in the case of the propulsion motors and manipulator motors.

Silicon control rectifiers are used for all ac switching functions. Propulsion power is switched as ac ahead of the variable voltage transformers which drive the propulsion motor rectifiers. Transistors are used to switch dc power to smaller motors, solenoids and the like.

Power contactors are used to reverse the propulsion motors but contacts are only broken at zero current and voltage.

V. SURFACE SUPPORT AND HANDLING EQUIPMENT

All surface support for RUM is provided by ORB (Oceanographic Research Buoy).

RUM is launched and retrieved through a 15 by 20-ft center well in ORB. Four steel cables tended by hydraulic cylinders snub RUM to restrain it from swinging during launch and retrieval. Divers are used to disconnect and connect these snubbers when RUM hangs safely below the bottom of the open well doors. When RUM is on board it rests upon the closed hydraulically actuated well doors.

The main hoisting winch is powered by a 50 hp, 240 V shunt wound dc motor. Speed control is by manually operated variable voltage transformers driving silicon rectifier bridges which supply armature and field power. Primary gear reduction is by standard 5-speed truck transmission and modified truck differential. Final reduction and drum drive is via 2-stage sprocket and roller chain. Cable is wound directly onto the winch storage drum under full tension. Level wind is accomplished by sensing the fleet angle of the wire and servo driving a pivoting lead sheave to maintain the proper angle. The winch is equipped with a large hydraulically actuated band brake on the storage drum and a solenoid actuated drum brake on the drive motor. Dynamic braking is used during pay-out by regenerating electrical power in the drive motor which is dissipated in a 32 kW resistor immersed in the 60 kW generator cooling water system.

The winch is equipped with an automatic cable tensioning system which can accommodate ± 10 -ft vertical excursions of the support platform with little change in cable tension. This system is described in some detail in reference II.

VI. SUPPORT VESSEL

ORB is a 45-ft square, 24-ft high box-shaped vessel displacing approximately 180 tons and having a 4-ft draft. It has a 15 x 20- ft center well with hydraulically actuated doors. The center well provides a sheltered area where RUM can be serviced as well as positioning it for launch and retrieval with minimal coupling to platform motion. ORB has no propulsion power but is normally towed to the operating area and moored. There are living accommodations and adequate laboratory and work space for 12 people including the 4-man crew.

DKG:cbb
Orig only
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REFERENCES

1. "RUM Vehicle System Description", MPL TM-216
2. Anderson, V. C., D. K. Gibson, O. K. Kirsten, RUM II, Remote Underwater Manipulator (a progress report) Marine Technology Society, Sixth Annual Reprints, Vol. 1, 29 June - 1 July 1970.